Final Draft Switchable Toll Tag Feasibility Study

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Prepared for

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1.0 Executive Summary

This paper summarizes the efforts of a study conducted July 2009 through May 2010 by the Bay Area Toll Authority (BATA) to evaluate the feasibility of implementing switchable self declaration toll transponders (herein referred to as switchable toll tags). In the Bay Area, the implementation of Express Lanes in various counties along with the planned development of an Express Lanes network and changes in bridge pricing provide a rationale to rethink the current toll tag technology. A self declaration toll tag would provide the functionality to allow customers to self-declare their vehicle occupancy status using a switching mechanism (e.g., slide, dial, push button, etc.) on the toll tag. In this way, the toll system will have the ability to calculate tolls based on up to three occupancy settings for each trip. Not only is this a non-intrusive way for users of the system to declare occupancy, but it also aids in both visual and automatic system toll enforcement.

Realizing the many benefits of a switchable toll tag, BATA investigated the near-term feasibility of implementing switchable toll tags in the Bay Area. This investigation explored a variety of issues and considerations associated with the implementation of switchable toll tags such as:

- implications for enforcement,
- technical feasibility,
- interoperability among other California toll facilities,
- user acceptance and design preference,
- timeline for procurement and replacement of legacy tags,
- economic considerations, and
- alternatives to switchable tags.

To be implemented in California, switchable toll tags must be able to transmit a standard California Code of Regulations (CCR) Title 21 signal with encoding to represent occupancy. Two different encoding methods were tested to transmit vehicle occupancy status using the standard Title 21 signal. Initial tests were performed with existing toll tags that were encoded with a unique toll tag identification prefix to distinguish occupancy setting. Subsequent testing was performed using switchable tag prototypes that incorporated a physical mechanism to manually change the occupancy setting and change the ID number of the toll tag.

The prototypes were provided by three vendors in response to an Invitation for Participation in a switchable toll tag prototype functionality test issued by BATA. Each of the three prototypes incorporated a different switching mechanism. After testing, these prototypes were presented to focus group participants who were asked to provide input on the design and functionality of the three designs.

Results of this study, documented herein, revealed the following:

- Switchable toll tags can be used to relay a vehicle's declared occupancy status to toll systems.
- Focus groups found that switchable toll tags are the preferred method for users to declare occupancy status, and preferred a switchable tag that incorporates a sliding switch mechanism (as opposed to a dial or button) to change occupancy status.

- Switchable toll tags will allow for automatic violation enforcement and provide consistency to users on corridors where carpool requirements vary.
- Level of interoperability is dependent upon encoding method. Two different Title 21 compliant encoding methods to represent vehicle occupancy were tested as part of this feasibility study:
    - Use unique identification numbers to correspond to each tag's occupancy setting: Compatible with all California toll agencies, but limits the number of tags that can be issued for each facility code.
    - Use the first four bits of the toll tag identification number to identify occupancy: Interoperable on all facilities with the tag in the SOV mode. Agencies can choose to process the other modes by the tag serial number or by using video toll to look up valid accounts by license plate.
- A cost-benefit analysis shows that revenue leakage can be reduced from 24% of gross revenue when no license plate recognition system is used to approximately nothing when an LPR system is used and all vehicles are required to have switchable toll tags.
    - If there are no violations or missed tag reads, gross revenue is estimated to be $21.2 billion over the next 20 years (in 2010 dollars, assuming the network is constructed over the next 10 years, lanes open as HOV 3+, and tolling is based on throughput maximization).
    - In the scenario using the legacy toll tag, 24% of gross revenue is lost due to violations and missed tag reads. Net revenue is $16.1 billion.
    - In the scenario using license plate recognition and requiring switchable toll tags in all vehicles, there is approximately no loss in revenue. The use of LPR allows the collection of revenue from vehicles with toll tag misreads, and the fines collected from violators covers all violators (including those that are not collectible). Net revenue is $20.9 billion after accounting for costs of capital and O&M and revenue from plate read transactions ($2.2 billion) and collected fees from violators ($2.6 billion).

2.0 Background and Rationale

Throughout the U.S., various metropolitan regions are exploring, developing, and implementing Express Lanes. Many first generation Express Lanes involved conversion of pre-existing, barrier-separated High Occupancy Vehicle (HOV) lanes with adequate right-of-way for positive separation between toll-paying vehicles (single occupant vehicles [SOV] equipped with a toll tag) and eligible free-use vehicles (e.g., carpools, low-emitting vehicles, motorcycles, etc.). However, as California has expanded the number of tolled Express Lanes in its various regions, the ability to identify various vehicles with minimal disruption to the existing traveler (both carpooler and toll user in the Bay Area) becomes important.

The Bay Area Toll Authority (BATA), Caltrans District 4, the Alameda County Congestion Management Authority (ACCMA), Santa Clara Valley Transportation Authority (VTA), and other regional agencies are developing a network of tolled Express Lanes (see Figure 1). As with all other California Express Lanes, the Bay Area network will use the Title 21 compliant FasTrak® electronic toll collection system for the collection of tolls. In the Bay Area, the implementation of an Express Lanes network and changes in bridge pricing provide a rationale to rethink the current toll tag technology. A switchable toll tag would provide the functionality to allow customers to self-declare their vehicle occupancy status using a switching mechanism (e.g., slide, dial, push button, etc.) on the toll tag. In this way, the toll system will have the ability to calculate tolls based on up to three occupancy settings for each trip. Not only is this a non-intrusive way for users of the system to declare occupancy, but it also aids in both visual and automatic system toll enforcement and allows for future tiered pricing based on vehicle occupancy.

Toll tag vendors are currently developing switchable toll tags for the toll industry, with initial interest concentrated in California, Virginia, Utah and Florida. Both LA Metro and the Riverside County Transportation Commission are planning on deploying Title 21 switchable toll tags on their Express Lane facilities. Realizing the many benefits associated with switchable tags, BATA has completed this feasibility study to determine whether the deployment of a switchable toll tag would be an effective means for occupancy declaration on Express Lanes in the Bay Area. The issues listed below served as the impetus for this study.

Enforcement

A key reason to require all vehicles to ultimately have toll tags is to enable the toll system to automatically enforce violations. When a vehicle passes a toll zone and does not have a toll tag or the toll tag is not read, there is no toll transaction. License plate recognition (LPR) cameras can serve this function. The License plate can provide billing information to a valid account or can be processed through a DMV look-up. LPR cameras cannot distinguish vehicle occupancy, though. An identifier is needed; a carpool with no tag will otherwise show up as a violator.

The switchable toll tag concept makes the toll tag the occupancy identifier by having a switch for users to set according to the vehicle's occupancy. Every vehicle using the express lane would be required to have a toll tag. In this scenario, vehicles with no tag or with tag misreads would be captured by the LPR system and charged a toll (if the vehicle is registered to an account) or a fine (otherwise). Note that carpools whose switchable tag is misread will be charged a toll, but a correction could be made to the account if the customer calls the customer service center.

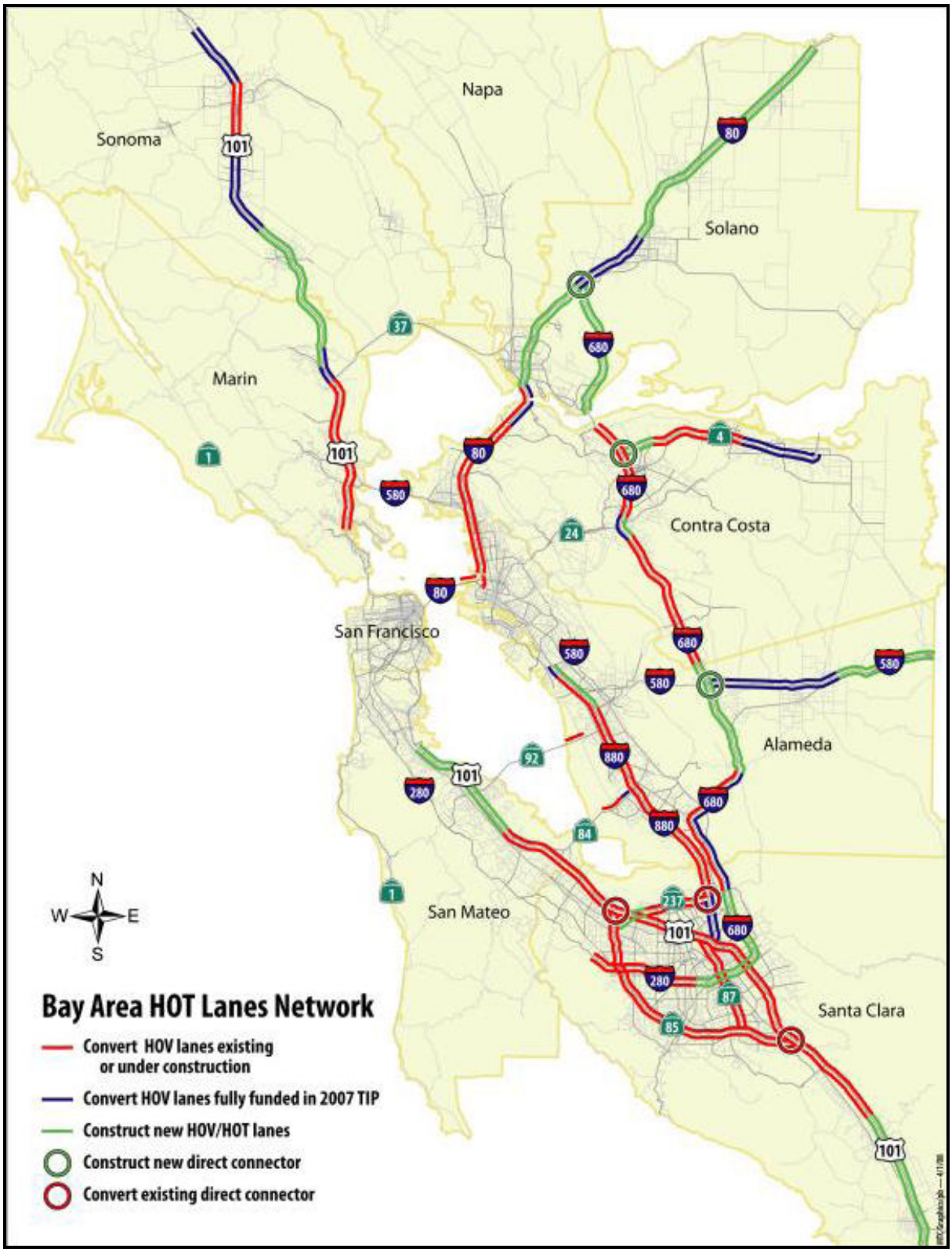

Figure 1. Bay Area Express Lane Network

Enforcement beacons at the toll zones can be used to alert CHP to the occupancy setting selected on the toll tag to improve visual CHP enforcement of the Express Lanes. These beacons would activate when a toll tag set in a HOV mode is read at a toll zone. A CHP officer downstream of the toll zone would see this beacon and make a visual observation of vehicle occupancy for the vehicle that passed through the toll zone, once the vehicle reaches the officer's position.. This would allow enforcement personnel to more easily identify occupancy violations.

Consistency

The existing Title 21 compliant toll tags in use on other facilities such as the I-15 in San Diego have worked reasonably well for customers who use the express lanes differentially as toll-paying SOV's or free-use carpools. For this facility, prior to beginning the trip, the customer may either place his or her toll tag on the windshield or remove the toll tag and place it in a static-free silver colored mylar bag. The latter prevents the toll tag from being read by the antenna and completing a transaction. Provided the customer has no need for paying tolls on that particular trip, the toll tag may remain in the static-free mylar bag without interaction during the trip.

On the Bay Area network, as well as for projects in the Los Angeles region, individual Express Lanes may have different occupancy policies. For example, one corridor may be HOV-2+ with free access, while another adjacent corridor may require HOV-3+ for free access. If these corridors intersect, then carpools on the former corridor would be required to pay a toll on the latter, and so would have to affix their toll tag to the windshield mid-trip. In Los Angeles, the occupancy requirements on the I-10 will change by time of day, meaning that an HOV-2 vehicle may be free one minute and tolled the next.

These scenarios place an additional burden upon the travelers to 1) know ahead of time the specific toll policies of each corridor, and, 2) be prepared to remove and/or place toll tags in accordance with each facility's policy. This process may be too onerous and unsafe to sustain support among the Express Lane customer base.

Additionally, Bay Area bridges will require HOVs to pay a toll and carry toll tags by July 2010, while the initial express lanes in the Bay Area will require HOVs to shield their toll tags. With legacy tags, a carpool would be required to shield its tag on the express lane, affix the tag to the windshield to cross the bridge, and then shield the tag after it crosses the bridge and enters the express lane. A switchable toll tag will spare drivers the inconvenience of having to mount and remove their toll tags by providing the ability to declare vehicle occupancy and allow the toll system to determine the appropriate fee at all facilities within the network.

When viewing each of these elements (occupancy by corridor, occupancy by time of day, charging of carpools) from a regional network perspective, the importance of a consistent toll tag policy for the customer is evident.

Right-of-Way Limitations

Another reason to consider the implementation of a new toll tag technology is the fact that many Express Lane facilities do not have the necessary right-of-way to allow for the separation of paying and non-paying vehicles into designated lanes. This highlights a need to efficiently identify which vehicles are required to pay a toll and which are eligible to travel for free. OCTA requires all vehicles on SR-91 to carry a toll tag. HOV and LOV vehicles are segregated by lane at the toll zone; one lane is for HOV use

and two are for LOVs. The expansion of the SR-91 Express Lanes to Riverside County has less right-of-way available, which limits the available width at the toll zones to two lanes. As a result, the RCTC is planning to implement switchable tags since all vehicles on SR-91 are required to carry a toll tag and there is no way to separate HOVs and LOVs in the confined setting.

3.0 Technical Feasibility

This section summarizes the details of several meetings with various groups that took place during the course of this study as well as the results of the switchable tag field tests.

3.1 Summary of Meetings

There have been several meetings with other toll agencies, California Toll Operators Committee (CTOC), CHP, toll tag vendors, and Caltrans to determine interest in switchable toll tags and identify interoperability concerns. Three vendors expressed an interest in providing switchable toll tags to BATA. Sirit, Transcore and Telematics Wireless are currently developing switchable tags for the toll industry. The manufacturers suggested using different identification (ID) numbers for occupancy setting or using the Tag Type. Caltrans is responsible for updating the CCR Title 21. There is discussion of revising the regulation to allow for other communication protocols but that would require legislation and would take years to take effect. Staying within the parameters of Title 21 is key to near-term implementation. Assigning agency codes and defining previously unassigned fields would not require changing Title 21. Prior to testing the switchable toll tag concept, BATA engaged in preliminary discussions with Caltrans relating to Title 21 requirements and possible methods to transmit vehicle occupancy status using a standard Title 21 transmission.

BATA asked specific questions to all agencies to better understand how each system processes the tag files. The responses from the agencies made it clear that toll tags with Tag Type IDs other than zero would likely cause problems for at least some agencies. To move forward with the procurement of prototype switchable tags for testing, the evaluation team decided that the prototypes should have three unique internal tag IDs to correspond to each of the three occupancy settings. This method avoids the concern of differentiating Tag Types and ensures the tags can be read at all toll facilities in all three settings.

3.2 Summary of Testing

California's Title 21 standard requires that all toll tags be encoded with a 32-bit toll tag identification number. This 32-bit identification number has been subdivided into three data fields to represent the Tag Type, facility code, and internal tag ID as shown in Table 1. The Tag Type is a 4-bit field that was established to provide the capability to differentiate other states' toll tags from California toll tags if a national agency numbering scheme were to be implemented in the future. Alternatively, the Tag Type field could be used to further describe the operational behavior of the toll tag. Currently, all California toll tags are Tag Type 0. The Colorado E-470 Public Highway Authority, the Denver International Airport and Golden Ears Bridge in Vancouver Canada all utilize Title 21 tags with Tag Type 2. This leaves 14 (2^4- 2 = 14) other unassigned designations that are available for potential assignment to other uses.

Table 1. Title 21 Standard Transponder ID Number Field

Tag Type ID	Facility Code	Internal Tag ID
4 Bits	18 Bits	10 Bits

Initial Testing

Initial testing was performed by modifying the Tag Type field of existing toll tags. A unique Tag Type ID was assigned to a different occupancy setting; the value of 0 was assigned to the SOV setting, the value of 1 to the HOV-2 setting, and the value of 5 to the HOV-3+ setting. To test whether this method of encoding would work, two existing toll tags were modified such that one had a Tag Type ID of 1, and the other a Tag Type ID of 5. In this way, the toll tag with a Tag Type ID of 1 would represent a switchable toll tag set to the HOV-2 setting and the toll tag with a Tag Type ID of 5 would represent a switchable toll tag set to the HOV-3+ setting. However, the valid tag file sent by BATA to the other California toll agencies had the Tag Type ID as 0 for both tags because of concern that a valid tag file with Tag Type IDs other than 0 might not be accepted by other agencies.

In September 2009, testing of the two modified toll tags was carried out on facilities representing each of the six California toll agencies. These agencies and the facilities they operate are listed below:

- South Bay Expressway
    - State Route 125 toll road
- San Diego Association of Governments (SANDAG)
    - I-15 Express Lanes
- Transportation Corridor Agencies
    - SR 73, SR 241, SR 133, and SR 261 toll roads
- Orange County Transportation Authority (OCTA)
    - SR-91 Express Lanes
- Golden Gate Bridge Highway and Transportation District
    - Golden Gate Bridge
- Bay Area Toll Authority (BATA)
    - Antioch, Benicia-Martinez, Carquinez, Dumbarton, Richmond-San Rafael, San Francisco-Oakland Bay and San Mateo-Hayward bridges.

Both modified toll tags were registered to a test account and driven through each facility. The toll transaction records were subsequently inspected to determine whether the transactions were properly recorded. The records showed transactions recorded on the BATA facilities and the Golden Gate Bridge, but did not show any transactions recorded on the southern California facilities. Because of the discrepancy between the Toll Tag ID of the tag versus the ID in the tag file, the toll tag ID numbers read in the lane were not correctly matched to the valid tag file for the southern California toll agencies and could not be reconciled with the test account. However, they did match on the BATA facilities because the Tag Type ID is not sent to the BATA lane controllers, and the lane controllers disregard the Tag Type ID when comparing tag reads to the stored tag numbers. Therefore, BATA facilities are able to correctly reconcile tag identification numbers read in the lane with the appropriate account since the Tag Type ID is ignored. However, this means that the current BATA system will not be able to differentiate tag numbers with different Tag Type IDs, unless there is a change in how the transaction data is processed. The software change could be at the lane level or at the back office or both, depending on how the toll is calculated.

Prototype Procurement

On September 29, 2009 BATA issued an Invitation for Participation (IFP) to purchase an initial quantity of functional Title 21 switchable prototype toll tags for testing. The IFP specified that the switchable tags should allow the user to declare a vehicle occupancy status of SOV, HOV-2, or HOV-3+ using an easily accessible switching mechanism. Each qualified firm wishing to participate was asked to manufacture and deliver ten switchable toll tags with any one type of switching mechanism. In response, three vendors provided a set of ten prototypes in December 2009. Each vendor's prototype incorporated a different switching mechanism to change the occupancy setting and was encoded with three identification numbers corresponding to each of the three occupancy settings. The three switching mechanisms consisted of a rotating dial by Telematics Wireless, a sliding switch by Sirit, and a push button by Transcore (see Figure 1).

Figure 1. Switchable Toll Tag Prototypes

Prototype Functional Testing

Initial field tests in December 2009 showed that two of the manufacturers had not encoded their tags correctly. It was found that the Tag IDs were converted directly from numeric to hexadecimal format without using the equation below, which illustrates how to properly convert Tag IDs to hexadecimal format.

Hex Value = HEX[(Facility Code * 1024) + Internal Tag ID]

where:

Hex Value = Tag ID in hexadecimal format
Internal Tag ID = last 4 digits of tag value
Facility Code = preceding 6 digits of tag value

The tags that were improperly encoded were returned to the vendors to be updated with the correct ID numbers and tests were continued.

Field tests of the updated switchable tag prototypes were carried out in February 2010 on toll facilities operated by each of California's six toll agencies. Tests consisted of driving through a toll zone with the switchable tag in the appropriate setting, manually recording the details of the pass through the toll zone, then reconciling the manual records with the toll transaction record. Results of the field tests were analyzed to determine whether each prototype was read as a valid transaction and whether the toll tag occupancy setting was accurately recognized.

From a functional standpoint, prototype testing revealed that switchable toll tags are feasible and can be encoded to represent vehicle occupancy. Although testing confirmed proof of the switchable tag concept, the performance of several of the prototypes confirmed that vendors would have to conduct rigorous testing to ensure a higher level of switch accuracy before procurement. Some of the tags switches did not reliably change the occupancy setting and others were not robust or durable enough to withstand repeated use.

4.0 Interoperability

As discussed in the previous section, two options for encoding vehicle occupancy using a standard Title 21 signal were considered during this feasibility assessment. Initial testing revealed that some of the existing toll systems would have to be modified to be able to read and recognize different Tag Type IDs. However, from a high-level perspective this is the preferred method to encode for vehicle occupancy. Alternatively, encoding a separate internal tag ID for each occupancy setting proved to be successful in terms of functionality and interoperability, but has the disadvantages discussed below.

4.1 Tag Type ID Encoding

The fact that the Tag Type ID number field currently has 14 unassigned designations makes it ideally suited to the purpose of representing vehicle occupancy. However, preliminary testing and discussions with toll agencies indicates that this option may not be currently interoperable among all California toll facilities. This is because all California toll tags currently carry a Tag Type of 0 and therefore some agencies have designed their toll systems to disregard the Tag Type ID or to check for Tag Type ID of 0 to verify it is valid tag. Using the Tag Type ID field to represent vehicle occupancy will likely require agencies, BATA included, to update their software systems to comply with Title 21 in order to recognize and accurately process the Tag Type ID to include occupancy settings.

In the current BATA toll system, the system host receives a tag file from the customer service center (CSC) that contains all valid toll tag identification numbers associated with active accounts. The toll tag identification numbers in this tag file do not include the Tag Type ID. The CSC then compares the truncated portion of the Tag ID to tags on the accounts and appends a "0" tag type when it forms the tag status file to send to the CTOC agencies. This shows that the lane controller also disregards the Tag Type when comparing the tag read in the lane with the tag status list in the lane controller. Also, transactions are sent from the Host to the CSC without the Tag Type in the transaction number

If BATA were to proceed using Tag Type ID to represent vehicle occupancy, then interoperability can still be maintained with other agencies even if they choose not to utilize the occupancy settings. One option would be to send these agencies a valid tag file that only includes 0 as a Tag Type ID. This would also alleviate concerns raised by both the CSC vendor and the new BATA toll system vendor regarding the increased tag file size if a tag status is sent for each of the Tag Type ID's. If a customer does travel on one of these facilities with his or her switchable tag set in a HOV setting, then the transaction may be identified as invalid and the customer's license plate will ultimately be used to reconcile the transaction. Customers from other agencies can still use their toll tags on Express Lane facilities, but will not be able to declare themselves as a HOV[1]. Alternatively, other agencies could make modifications to their toll system to recognize the tags in the HOV switch settings and still charge the appropriate SOV toll at their facilities. Table 2 briefly summarizes some of the details of other California agencies' toll systems.

[1] Overhead signage will indicate that the Express Lanes are for "FASTRAK ONLY" in a purple banner, as shown in the 2009 US MUTCD. This will be the drivers' notice that a valid toll tag is required for all vehicles, including carpools. HOVs with a legacy toll tag will be charged a toll; whether or not such customers would be refunded if they call in would be a business decision by the toll facility's toll agency.

Table 2. Summary of Toll Systems in California

Agency	Existing Systems	Carpool	Implementation
SBX	InTrans	No discount for carpool	Existing system reads the tags correctly in the lane but the central system does not accept tag type ID other than"0". Vehicles with switchable tags set to HOV will be caught by the LPR system and assessed a toll.
SANDAG I-15	Transcore	Carpool free, no toll tag required	The service center could accept the file but the tags with a tag type ID other than "0" would be considered invalid. Since that would be the case when the tag is switched to carpool, and since carpools are free, the switchable tags would not present a problem for SANDAG. Vehicles with switchable tags set to HOV will be ignored.
TCA	Sirit System VESystems – back office Transcore - Maintenance	No discount for carpool	Existing system does not accept tagtype ID other than "0". System will work if tag type ID is "0" for cars using TCA facilities. If other settings are used license plate can be used to charge correct account. Vehicles with switchable tags set to HOV will be caught by the LPR system and assessed a toll.
OCTA	Sirit Lane Equipment Telvent – back office	Carpool (3+) free during most hours, must have toll tag and drive through designated lane	Existing system does accept tag type ID other than "0". Central system will accept valid tag file and lane will process tags correctly.
RCTC	TBD	Carpool free, toll tag will be required	Planning to implement system using switchable toll tags
LA Metro	TBD	Carpool free, toll tag will be required	Planning to implement system using switchable toll tags

4.2 Unique Internal Tag ID Encoding

Prototype testing was performed using switchable toll tag prototypes encoded with three unique internal Tag IDs corresponding to each of the three occupancy settings. This concept proved to be interoperable on all facilities since it only required that the three internal Tag IDs associated with each toll tag be sent to each of the agencies in the valid tag file. However, assigning three different internal Tag IDs to an individual account significantly limits the number of accounts that can be established for each facility code. As mentioned previously, each toll tag is encoded with a 32 bit toll tag identification number divided into three fields. One of these fields, the Facility Code, is used to distinguish toll facilities. Each facility is allotted a range of Facility Codes, and each Facility Code can only accommodate a block of 1,024 Internal Tag IDs. Since every switchable toll tag that is issued would require the allocation of three Internal Tag IDs instead of one, the number of accounts associated with each Facility Code would be reduced from 1,024 to 341 tags. This would require additional Facility Codes be assigned to participating agencies to ensure that a sufficient number of switchable toll tags can be issued. Currently, there are 2,041 facility codes assigned to BATA (see Caltrans ATCAS facility codes in Table 3). Since each facility code allows for the issuance of 1,024 toll tags, there is a current limit of 2,089,984 toll tags. Assigning three different IDs for each tag would effectively reduce this number to one-third, or 696,661, assuming that all tags are changed to switchable tags.

Table 3. Facility Codes Assigned to State Toll Agencies

Facility Codes		
Agency	*Facility Codes Assigned*	*No. of Transponders*
State of California	0 – 125,000	128,001,024
Sacramento County Dept. of Airports	125,001 – 125,020	19,456
TCA	130,047 – 132,092	2,095,104
SR-91	132,096 – 132,607	524,288
SANDAG I-15	132,992 – 133,001	10,240
Golden Gate Bridge	133,015 – 133,407	402,432
CTV	134,583 – 134,876	301,056
SENTRI	184,876 – 185,022	150,528
SANDAG I-15	258,960 – 259,014	55,296
Caltrans ATCAS	260,096 – 262,136	2,089,984

As with the previously discussed system of encoding, legacy tags would still work on this new system. Users with legacy tags would not be able to declare a HOV status and therefore would not be able to receive the benefit of a reduced toll for traveling in a carpool. A switchable tag with three separate IDs used on other facilities would be read and processed as a valid tag but the status of HOV2 or HOV3 would not be known to that facility.

An interim step to expedite the implementation of switchable tags in the Bay Area may be to initially use an encoding scheme that assigns unique tag IDs to each occupancy setting then transition to using Tag Type ID for occupancy in the future. Proceeding in this way would allow switchable tags to be deployed while CTOC agencies and Caltrans work to define Tag Type ID designation. However if the Tag Type ID standard is released prior to the procurement of the switchable toll tags, this interim step would not be required.

5.0 Focus Groups

Recognizing that the adoption of switchable toll tags will be dependent upon not only the successful communication and encoding from a technical perspective, but also the human-based interaction with the toll tag devices, BATA commissioned focus group sessions in February 2010 to observe perceptions of and attitudes toward the Title 21 switchable prototype toll tags, and, discuss alternatives in lieu of the switchable toll tag concept. During each of the focus group sessions, participants were able to interact with each of the prototypes and comment on features that they liked and disliked. These comments were used to gauge general preferences for design features of switchable toll tags.

Two focus groups were conducted. The first group consisted of twelve individuals who had toll tag accounts and the second group consisted of nine individuals who did not have toll tag accounts. The purpose of holding each group separately was to observe any differences in attitude that may exist between current toll tag users and those who did not use toll tags. Both groups were comprised of residents of the geographic area bounded by Vallejo, Pleasanton and Fremont who ranged in age from 22 to 68 and represented diversity in income level and occupation.

After familiarizing participants with the Express Lane concept, the three different switchable toll tag prototypes were passed out in succession. All participants had an opportunity to physically interact with each of the prototypes and provide their opinions of each of the switching mechanisms. Both groups had very similar opinions of the tags. General comments and opinions expressed during the focus groups are listed below:

<u>Attitudes Toward the Button Tag</u>
The button was generally viewed unfavorably by both groups. The comments about the button tag included:

- No intuitive visual indicators or guidance on how to operate the tag.
- The button is too small and thin, making it difficult to press.
- When the button is pressed, the thumb blocks the light indicator, therefore the button should be moved to the right hand side of toll tag.
- The design makes it too easy to set the tag in the wrong mode. There needs to be a visual confirmation of selected occupancy setting so users do not forget to reset the tag with the correct number of passengers.
- The indicator lights are too small, not bright enough, and would be difficult to see in bright light or when it is dark. Also, the operation of the indicator lights was found to be confusing.
- Some participants preferred a separate push button (if buttons were big enough) for each setting (e.g., one, two or three-plus), such that the button of the selected setting remained depressed until a new setting was chosen.

Attitudes Toward the Dial Tag

While the dial was preferable to the button tag (the size, look and color rated better, visual feedback better, people icons more intuitive), concerns expressed by participants in both groups related to the dial itself:

- The dial was too small, slippery, and difficult to adjust when mounted behind the rearview mirror because knuckles get in the way. To improve the design, participants indicated that the raised portion of the dial should be bigger and the dial should click into place at each setting.
- Concern that the dial would wear out over time.
- The dial tag does not give audible feedback when the setting was changed. Some respondents didn't think a verification beep was necessary when setting the tag because the icons were a clear confirmation; others wanted to hear the feedback beep.

Attitudes Toward the Switch Tag

The switch was viewed most favorably. Generally, participants found it functional, reliable and utilitarian. However, concerns and suggestions for improvements included:

- Lettering is too small and difficult to understand (what does HOV mean?); pictograms were preferred.
- Switch could be improved: some participants noted that it is hard to move, protrudes too much (citing that it might break easily and hurts portability of tag), and middle setting (HOV 1) is difficult to locate.
- Settings should be in increasing order of occupancy (i.e. from left to right, SOV, HOV-2, HOV-3+)..

The concept of a carpool registration system, where users would call the customer service center to declare occupancy on a per-trip basis or according to a schedule, was also explained to focus group participants as an alternative to using switchable tags. All of the participants were adamantly opposed to the option of registering (either by phone or by website) ahead of time to declare their carpool status. They generally felt this was burdensome, inconvenient, and inefficient and participants left no doubt that they preferred a switchable toll tag.

6.0 Schedule for Implementation

Determining if and when to implement switchable toll tags is a precursor to finalizing all other steps required to rollout the tags. Before proceeding with implementation, an important policy change that must be agreed on by the HOV Committee (consisting of Caltrans D4, MTC, and CHP) and the Express Lanes Management and Operations Committee (MOC) is that all carpool vehicles using express lanes will be required to have a toll tag. Furthermore, all express lanes should be required to have a license plate recognition system.

Implementation of switchable tags in the Bay Area requires specific targeted planning, marketing, signage, and testing tasks. Planning tasks include final decision implementation, developing roll out schedule, allocate or establish support budget, and finalizing the preferred method of tag encoding. Planning tasks also need to include finalizing the overall approach for marketing the new self declaration tags.

For a new vendor or a new version of a toll tag the Title 21 testing should be done to verify compliance. It is recommended that prior to a procurement selection the vendors provide independent Title 21 test documentation to be considered a qualified proposer. After a vendor is selected, the switch mechanism and graphics will need to be finalized. Prior to production manufacturing, a beta test is recommended to verify that the new design meets all environmental and performance requirements. The beta test would verify the new tag design meets temperature specifications, shock and vibration requirements, and read accuracy requirements prior to the production deployment of tags. The schedules shown in Table 4 and 5 provide an estimated timeframe for each of the remaining tasks that would need to take place should BATA decide to proceed with the implementation of switchable toll tags.

Table 4. Switchable Tag Procurement Schedule

Task	Duration	Start	Finish
Evaluate Tag Options	**6 months**	**1/2010**	**6/2010**
Policy	**5 months**	**6/2010**	**10/2010**
Decision to use Switchable Tag	3 months	6/2010	8/2010
Draft Title 21 assignment of TagTypeID (if agreed approach)	3 month	8/2010	10/2010
BATA Tag Procurement	**10 months**	**10/2010**	**7/2011**
Selection of Title 21 compliant vendor	2 months	10/2010	11/2010
Beta Test – environmental and performance	2 months	12/2010	1/2011
Manufacture Tags	6 months	2/2011	7/2011
Tag Distribution	**on going**	**8/2011**	

Table 5. Switchable Tag Roll-Out Schedule (Bay Area)

Task	Duration	Start	Finish
System Upgrade	**5 months**	**10/2010**	**2/2011**
Determine Bata System Upgrades	1 month	10/2010	10/2010
Upgrade and Test System	4 months	11/2010	2/2010
Signage	**5 months**	**6/2011**	**10/2011**
Develop New Signage Plan	2 months	6/2011	7/2011
Order New Signs Panels/Overlays	2 months	8/2011	9/2011
Delivery and installation	1 month	10/2011	10/2011
Marketing	**10 months**	**1/2011**	**10/2011**
Develop Marketing Plan	4 months	1/2011	4/2011
Public Awareness of Policy Change	6 months	5/2011	10/2011
Education Campaign on Tag Usage	4 months	7/2011	10/2011

7.0 Bay Area Replacement and Roll-out

The transition to a different toll tag has both near- and long-term implications to all partnering agencies. The most efficient way to implement switchable toll tags would be to gradually phase them in as a replacement for targeted users of legacy tags and for all new customers. As mentioned previously, legacy tags will still work for SOVs even after switchable tags are implemented, so there is no immediate need to issue a complete replacement of legacy tags. Many customers can continue to use legacy tags as long as they are charged at the SOV rate. Customers who currently carpool in the affected corridors would be targeted for switchable tags.

There are several scenarios for the roll out of the switchable toll tags. The ideal scenario is to have the switchable toll tags distributed prior to the opening of the I-580 Express Lanes. By 2015 the I-580 is expected to have 187,000 LOVs and 34,000 HOVs. The increased annual revenue realized by utilizing the switchable toll tags for I-580 is $3.8 million. The Express Lanes are scheduled to be operational by summer 2011. The tags should be available for distribution at least two months prior to the facility opening to Express Lane traffic, but could be made available earlier.

One option would be to continue to always have both switchable toll tags and standard toll tags available for purchase; however, this may lead to confusion for the traveling public. A preferred option would be to reach a point in time when the inventory of legacy tags is exhausted, and all new and replacement toll tags are the switchable kind. Marketing material could be sent to all existing toll tag account holders explaining the advantages of the switchable toll tags and allowing them to exchange their existing toll tag for a new switchable toll tag. This information could be included in the statement giving customers the option to keep their existing tag or exchange it for the switchable type. To facilitate the exchange, BATA could include a return envelope with the new tag and/or establish convenient drop-off locations, and allow a certain number of days for the receipt of the old tag. If the old tag is not returned then the customer would be charged the tag deposit fee.

Several items have to be accomplished prior to the distribution of the new toll tags:

- The toll tags themselves have to be procured, tested, and available for distribution.
- The service center needs to be upgraded to receive into inventory and process switchable toll tags.
- The service center would also have to verify correct handling of occupancy in the transaction processing.
- Reports would need to be revised to display occupancy and appropriate tolls.
- Signage requiring all users of the facility to have toll tags would need to be procured and installed.
- Marketing material and FAQs would need to be developed to explain the new toll tags and the benefits to the traveling public.
- Website would have to be updated to explain the benefits of the new toll tag
- Staff training would need to occur to prepare for operational questions and concerns.

8.0 Cost-Benefit

A cost-benefit analysis was performed to determine the difference in revenue generation between a build case, using license plate recognition (LPR) system in conjunction with switchable tags, and the no-build case with no LPR system and with legacy tags.

Major assumptions made were as follows:

Implementation: The analysis was performed over a 20-year period and assumed the 800-mile network was developed over the initial 10 years. All costs were in 2010 dollars with no escalation.

Traffic and revenue model: The model (generated in prior MTC studies) that was used assumed express lanes opened as HOV 3+ and the tolling algorithm was set to maximize throughput (as opposed to revenue). This model results in gross revenue of $21 billion.

Alternative models assuming HOV 2+ requirements were not used because the system degrades as traffic levels rise in later years until no revenue is generated on several corridors. A hybrid, model where corridors open as HOV 2+ and convert to HOV 3+ as the throughput levels degrade, has not been finalized and was not available for this study.

Violation rates: These were determined by looking at Caltrans' estimate of existing HOV lane peak period violation rates. For freeways, the rate varies between 0% and 6%, while at toll plazas the rate is closer to 12%.

In the no-build case violations, violators are LOVs who do not have a FasTrak account. The analysis assumes 8% of vehicles in this case are violators, a figure that is in between the Caltrans HOV lane and toll plaza rates. In the build case, violators are HOV and LOV vehicles who do not have a FasTrak account combined with LOV vehicles who willfully set their tags to HOV mode. The addition of LPR was assumed to dissuade drivers without accounts from using the express lanes; only 4% of all vehicles were assume to have no account. An additional 4% of vehicles were assumed to be LOVs who willfully set their tags to HOV mode.

Tag reader and plate reader accuracy: These were determined by using the statistics for the state-owned toll bridges. Tag readers are assumed to have a read rate of 84% (tags do not read, for example, when they are not displayed properly or the battery has died). The LPR system has plate read rate of 81%.

Fine structure: In the no-build case, violators can only be caught by CHP. Tickets issued by CHP are court citations for occupancy violation; revenue generated from these tickets do not go to the toll agencies. As such, the no-build case did not include any revenue from fines. In the build case, the LPR system will capture violators who have no account. The fine structure was modeled after the state-owned toll bridges: the average collected fine is $30. The revenue generated from the fines is approximately equal to the transaction cost and the lost revenue for all violators.

Capital and O&M costs: For the build case, these include the additional cost due to the greater number of toll tags distributed, the LPR capital cost, and the processing fee for plate reads ($0.09) and fine notification ($2.00),

The results of the cost-benefit analysis are shown in Table 6. The major conclusions are as follows:

1. The build case sees a $4.8 billion benefit over the no-build case (approximately 20% of gross revenue).

2. If the violation rate is 0, the net benefit of the build case is $2.2 billion, which is revenue collected from account-holding LOVs who are misread by the tag reader and read by the LPR system (~10% of gross revenue)

3. An additional $2.6 billion is generated from fines. This revenue is directly proportional to the average fine of $30; a $60 fine would generate $5.2 billion (assuming a constant rate of collection).

Table 6. Cost-Benefit Results

Gross revenue, assuming no leakage = $21.2b

No-build case: Legacy Tag

	Case	%	Outcome	Revenue	Cost
1	LOV with account, tag read	63	revenue	$16.1b	$0
2	LOV with account, tag misread	12	no revenue		
3	LOV with no account	8	no revenue for toll agency		
4	HOV	17	no revenue		
		100		**Net Revenue: $16.1b**	

Notes:

A: Revenue Leakage = (2+3) / (1:3) = 24%

Build case: Switchable Tag and LPR

	Case	%	Outcome	Revenue	Cost
1	LOV with account, tag read	63	revenue	$16.1b	
2	LOV with account, tag misread, plate read	9.7	revenue	$2.9b	$0.7b
3	LOV with account, tag misread, plate misread	2.3	no revenue	$2.6b (from fines)	$0 (all cost accounted for in $0.7b above)
4	No account, no plate read	0.8	no revenue		
5	No account, plate read, fine collected	1.6	fine		
6	No account, plate read, fine not collected	1.6	no revenue		
7	LOV with account, tag switched to HOV	4	no revenue for toll agency		
8	HOV with account, tag read	17	no revenue		
		100		**Net Revenue: $20.9b**	

Notes:

A: 3+4+5+6 = ~revenue neutral if fines are collected (average collected fine = $30)

B: Revenue Leakage (accounting for fines) = 7 / (1:7) = 4.8%

C: Revenue Leakage (not accounting for fines) = (3+4+6+7) / (1:7) = 11%

9.0 Other Alternatives to Switchable Toll Tags

Alternatives to switchable toll tags involve the following mechanisms:

9.1 Dual-mode Applications

The FasTrak® toll tag is the standard application in the Bay Area and throughout California, and its current mechanism for Express Lanes is cumbersome. As described for I-15, prior to the commencement of the trip, the customer either places the toll tag on the windshield (for use as a toll-paying customer) or in a static-free ("silver") bag for use as a carpooler or other eligible toll-free user. Similar applications are in use in other regions of the country. Washington State, for example, has a shield that is placed over the windshield mounted sticker toll tag, which prevents transactions from registering. Likewise, Minnesota's toll tag involves a windshield-mounted cradle (see Figure 3). When the toll tag is in the cradle, a circuit is made and transactions may proceed; if the toll tag is out of the cradle, the transponder is off and no transaction is completed. All of these options pose complexities to the end user and can result in missed reads or overcharges.

Figure 2: Minnesota MnPass Toll Tag and Windshield-mounted Cradle

In all cases, there are only two modes to the toll tag – on or off. In the "on" mode, a toll transaction is completed; in the "off" mode, no transaction would occur. There is no provision in the dual-mode application for tiered pricing, which does not meet the Bay Area network's objective associated with efficiency through tiered pricing. More importantly, this process may require customers to switch modes in the middle of a trip, as bridge-crossing carpools will be required to display a toll tag. So, in this operational mode, it is possible that a 2-person carpool trip begins with an HOV-3+ Express Lane (toll tag on to pay the toll), continuing onto an HOV-2+ Express Lane (toll tag off no toll since they meet the HOV requirements), and completing with a bridge crossing (toll tag on). In this example, the customer must change the toll tag mounting twice in-trip.

9.2 Static Carpool Registration

Another alternative to the use of switchable toll tags is a carpool registration program, as is currently used on I-95 in Miami. All LOV vehicles traveling on the 95 Express Lanes in Miami are required to carry a toll tag. Registered carpools with three or more occupants are eligible to use the lanes for free. Once registered, a sticker decal is issued to the carpool vehicle(s), and is affixed to the bumper to allow Highway Patrol easy identification of those HOV vehicles.

For the Bay Area, this process would allow BATA to maintain the use of existing FasTrak® toll tags, but the idea of registering carpools has met political resistance, particularly given the Bay Area's widespread use of casual carpools.

9.3 Pre-Trip Carpool Declaration

The I-85 HOT Lane project in Atlanta is developing a carpool declaration process that allows for casual carpooling. All Express Lane customers must be equipped with a toll tag. If a traveler wishes to use the HOV-3+ toll-free option, he or she must pre-declare via website or telephone the intention to use the lanes as a carpool. The carpooler would log on, provide the toll tag number (likely linked to a previously established account), and declare the correct carpool status.

Video tolling could also be implemented with a carpool registration. In this way, motorists would be required to register the vehicle's license plate with the tolling agency prior to using the Express Lanes. When a toll transaction is made, the toll system will then associate the plate images with the account and debit the amount of the toll from the account. Similar to the toll tag carpool registration system, a motorist wanting to use the lane as a toll-free carpool would have to pre-declare their intent to travel as a carpool. The difference is that motorists would not be required to carry a toll tag to travel on the Express Lanes.

If applied to the Bay Area, a carpool declaration system could be implemented with the existing FasTrak® toll tags without issuance of new accounts. . The system would permit tiered-pricing—users would call the CSC prior to the trip and declare the vehicle's occupancy. As such, this system would allow for trips on multiple facilities with varying occupancy requirements without the need to adjust or remove the toll tag. However, this system would likely carry higher administrative costs and may pose concerns to CHPs since the enforcement personnel's knowledge of declared status in the field could be compromised. To ensure the ability to enforce, the carpool registration would have to be completed early enough to be sent by the back office to the lanes so the officer can know which vehicles are registered.

When discussed with the Bay Area focus group participants, all were adamantly opposed to the option of registering ahead of time to declare their carpool status. Participants believed it to be burdensome, inefficient, and prone to error.

10.0 Conclusions

The appeal of switchable tags for the Express Lanes in the Bay Area is evident. As noted throughout this report, there are many operational benefits associated with switchable toll tags. The most notable benefit is the fact that switchable tags allow for improved enforcement via LPR technology. This reduces the burden placed on CHP for enforcement and improves overall efficiencies of the toll system. Switchable tags also provide users with a consistent and easy to use means for declaring vehicle occupancy on Express Lanes and Bay Area bridges.

The results of this feasibility study support the implementation of switchable tags in the Bay Area from both a technical and economic perspective. Field testing revealed that the concept is technologically feasible and can be made to be interoperable on toll facilities throughout the state. Focus group participants supported the switchable tag concept and provided valuable feedback to guide the functional design of switchable tags. The implementation of switchable toll tags makes sense from an economic perspective as well. Analysis of the benefits and costs associated with migrating to a switchable tag system revealed large benefit and would represent a sound investment for Bay Area express lanes.